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ORIGINAL COMMUNICATION

Use of EEG in critically ill children and neonates in the United States of America

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Abstract The objective of the study was to estimate the proportion of patients who receive an electroencephalogram (EEG) among five common indications for EEG monitoring in the intensive care unit: traumatic brain injury (TBI), extracorporeal membrane oxygenation (ECMO), cardiac arrest, cardiac surgery and hypoxic-ischemic encephalopathy (HIE). We performed a retrospective cross-sectional descriptive study utilizing the Kids' Inpatient Database (KID) for the years 2010–2012. The KID is the largest pediatric inpatient database in the USA and it is based on discharge reports created by hospitals for billing purposes. We evaluated the use of electroencephalogram (EEG) or video-electroencephalogram in critically ill children who were mechanically ventilated. The KID database had a population of approximately 6,000,000 pediatric admissions. Among 22,127 admissions of critically ill children who had mechanical ventilation, 1504 (6.8%) admissions had ECMO, 9201 (41.6%) TBI, 4068 (18.4%) HIE, 2774 (12.5%) cardiac arrest, and 4580 (20.7%) cardiac surgery. All five conditions had a higher proportion of males, with the highest (69.8%) in the TBI group. The mortality rates ranged from 7.02 to 39.9% (lowest in cardiac surgery and highest in ECMO). The estimated use of EEG was 1.6% in cardiac surgery, 4.1% in TBI, 7.2% in ECMO, 8.2% in cardiac arrest, and 12.1% in HIE, with an overall use of 5.8%. Among common indications for EEG monitoring in critically ill children and neonates, the estimated proportion of patients actually having an EEG is low.

Keywords EEG · Video EEG · Critical care · Pediatric · Health services research

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Introduction

Electrographic seizures have an incidence of 10–42% in critically ill children who had clinically indicated continuous electroencephalogram (cEEG) monitoring [1–13]. By definition, electrographic-only seizures have either none or only very subtle clinical correlates and therefore can only be detected when the patient is on EEG. In a multicenter study of 550 children with clinically indicated cEEG monitoring, 162 (30%) patients had electrographic seizures. Out of these 59 (36%) were electrographic only, reflecting an overall rate of 10.7% of electrographic-only seizures in their population [14]. In some conditions with high prevalence of electrographic seizures, a cEEG is often indicated even without a clinical suspicious of seizures [15, 16].

The use of cEEG for the diagnosis and management of electrographic seizures and electrographic status epilepticus has increased in the intensive care unit (ICU) [17–19]. A series of 236 children and adults looked at patients in a coma in the ICU with no clinical signs of status epilepticus, and they reported that 8% had electrographic seizures [20].

The American Clinical Neurophysiology Society (ACNS) published expert-based guidelines for the use of cEEG monitoring in children, adults [15] and neonates [16], and recommended the use of cEEG in conditions with high risk of subclinical seizure such as traumatic brain injury (TBI), extracorporeal membrane oxygenation (ECMO), cardiac arrest [15], cardiac surgery and hypoxic-ischemic encephalopathy (HIE) [16], among others. Additionally, there is also evidence that cEEG can assist in the assessment of severity and prognosis of encephalopathy [15], in particular after cardiac arrest [21–26] and TBI [23, 27].

A study using the discharge data from the Nationwide Inpatient Sample (NIS) database with 40,945 adult discharges reported that cEEG was associated with inpatient survival in mechanically ventilated patients, and this did not add substantial costs to the hospital stay of the patients [19]. It is, however, unknown how many critically ill children undergo cEEG monitoring and how indication rates vary based on different conditions. Available estimates are based on surveys to highly specialized neurologists in tertiary centers [28–30], and may not represent the use of cEEG in the USA.

To address this gap in knowledge, we studied the Kids' Inpatient Database (KID) to evaluate the use of EEG in five different conditions with high risk of subclinical seizures: TBI, ECMO, cardiac arrest, cardiac surgery and HIE. Information about EEG use in critically ill children may help identify conditions or settings where cEEG is underused and may guide future policies and guidelines to remediate these gaps.

Methods

Standard protocol approvals, registrations, and patient consents

We used a de-identified pediatric database from the Health Care Cost and Utilization Project (HCUP). The Institutional Review Board at Boston Children's Hospital determined this study to be non-human research.

Study design

We performed a retrospective cross-sectional descriptive study on the Kids' Inpatient Database (KID) for the years 2010–2012. The KID becomes available in 3-year bundles, and the 2010–2012 bundle represents the most recent available years.

Database

HCUP is the largest all-payer encounter-level hospital care data in the USA [31], and it is based on administrative data—discharge abstracts created by hospitals for billing [32].

Currently, HCUP has health care data from 47 states, representing 97% of all inpatient hospital discharges [31]. The KID is the largest publicly available, all-payer pediatric inpatient database in the USA [31]. It contains an unweighted sample of approximately three million pediatric hospital discharges from 2500 to 4100 community non-rehabilitation hospitals per year [31, 32]. Weighted, it estimates approximately six million hospitalizations [32].

Inclusion criteria

We included children (age 0–20 years) who were hospitalized and had the diagnosis/procedure of ECMO, TBI, HIE, cardiac arrest or cardiac surgery, and who were also intubated.

Variables

Our primary outcome was the use of EEG (ICD-9-CM code 8914) or video-electroencephalogram (vEEG) (ICD-9-CM code 8919) during hospital admissions with five different severe conditions: ECMO, TBI, HIE, cardiac arrest and cardiac surgery. For HIE, we only included neonates. For cardiac arrest we only included patients over one year of age. The codes for identifying admissions that reported ECMO, TBI, HIE, cardiac arrest and cardiac surgery are available in Table 1. We included these admissions only if they also had intubation during their hospitalization, as this can reflect the severity of the patients. Intubation was defined using ICD-9-CM codes 9601, 9602, 9604, 9605, 9607, 9670, 9671, 9672 (Table 1). We also included demographic characteristics such as age, gender, race, income quartiles, length of hospital stay, and death.

Weighting

The KID database is a sample of all pediatric admissions in the USA. The process of weighting observations is performed by the HCUP. In order to produce national or regional estimates of pediatric hospitalizations using the KID, discharge weights are developed using the American Hospital Association (AHA) target universe as the standard. To do so, KID records are post-stratified by USA region, urban or rural location, teaching status, ownership, and bed size with the addition of a stratum for freestanding children's hospitals. Details of the sampling strategy can be found at https://www.hcup-us.ahrq.gov/tech_assist/sampledesign/508_compliance/508course.htm and https://www.hcup-us.ahrq.gov/tech_assist/sampledesign/course/course.htm.weights permit generation of national estimates. The database documentation also contains additional details on weight development [32].

Table 1 ICD9 procedure and diagnosis codes used in the analysis

Code	Description
Electroencephalogram	
89.14	Electroencephalogram
89.19	Video and radio-telemetered electroencephalographic monitoring
Extracorporeal membrane oxygenation	
39.65	Extracorporeal membrane oxygenation
Traumatic brain injury	
800	Fracture of vault of skull
801	Fracture of base of skull
803	Other and unqualified skull fractures
804	Multiple fractures involving skull or face with other bones
850	Traumatic brain injury
851	Cerebral laceration and contusion
852	Subarachnoid subdural and extradural hemorrhage following injury
853	Other and unspecified intracranial hemorrhage following injury
854	Intracranial injury of other and unspecified nature
Hypoxic-ischemic encephalopathy	
437.9	Cerebral hypoxia
768.7	Ischemic, in newborn
768	Intrauterine hypoxia and birth asphyxia
Cardiac arrest	
427.5	Cardiac arrest
Cardiac surgery	
35.1	Open heart valvuloplasty without replacement
35.2	Replacement of heart valve
35.4	Production of septal defect in heart
35.5	Repair of atrial and ventricular septa with prosthesis
35.6	Repair of atrial and ventricular septa with tissue graft
35.7	Other and unspecified repair of atrial and ventricular septa
35.8	Total repair of certain congenital cardiac anomalies
35.9	Other operations on valves and septa of heart
Intubation	
96.01	Insertion of nasopharyngeal airway
96.02	Insertion of oropharyngeal airway
96.04	Insertion of endotracheal tube
96.05	Other intubation of respiratory tract
96.07	Insertion of nasogastric tube
96.70	Continuous invasive mechanical ventilation of unspecified duration
96.71	Continuous invasive mechanical ventilation for less than 96 consecutive hours
96.72	Continuous invasive mechanical ventilation for 96 consecutive hours or more

Statistical analysis

For the analyses, we used complex survey weights and procedures for appropriate national projections. We summarized demographic and clinical characteristics with descriptive statistics. As this database is de-identified and based on hospital admission, some data may belong to the same individual. Thus, the assumption of independence does not hold, and we did not perform comparative statistics. All statistical analyses were performed using SAS software, version 9.4 (SAS Institute Inc., Cary, NC, USA).

Results

The KID database had 3,195,782 pediatric admissions, and the weighted population had 6,675,222 pediatric admissions. Table e-1 describes the demographic characteristics of the hospitals included in the KID database.

There were a total of 1504 admissions that coded ECMO, 9201 with TBI, 4068 with HIE, 2774 with cardiac arrest, and 4580 admissions with recorded cardiac surgery (Table 2). All of these admissions also coded mechanical ventilation. Table 2 summarizes the demographic characteristics of ECMO, TBI, HIE, cardiac arrest and cardiac surgery (Table e-2 summarizes the unweighted data). All five conditions had a higher proportion of males, with the highest percentage of males (69.84%) in the TBI group. The mortality rates ranged from 7.02 to 39.92% with the lowest one in the cardiac surgery group and the highest mortality rate in the ECMO group. The length of hospital stay ranged from 11.94 days in the TBI group to 40.21 days in the ECMO group.

Figure 1 summarizes the use of EEG, vEEG, and the combination of vEEG and/or EEG in the admissions that reported ECMO, TBI, HIE, cardiac arrest, or cardiac surgery. The group with lower use of any type of EEG was cardiac surgery (1.61%), followed by TBI (4.10%), ECMO (7.19%), cardiac arrest (8.21%), and HIE (12.14%). The overall use of EEG was 5.79% (Table 3; Table e-3 summarizes the unweighted data).

Table 4 provides the demographics of the admissions with reported EEGs in pediatric hospitals in the USA (Table e-4 summarizes the unweighted data). Out of all hospital admissions in the KID database, 40,596 (0.61%) reported the use of some type of EEG. Some of these admissions had a code for EEG and others for vEEG. The vEEG code was more frequently used in Whites, and the EEG code was more used in Blacks and Hispanics. Similar differences were found for socioeconomic status with vEEG code being used slightly more frequently in the higher socioeconomic quartiles (Table 4).

Discussion

The estimated use of EEG (either video or routine EEG) was 1.61% in cardiac surgery patients, followed by 4.10% in TBI, 7.19% in ECMO, 8.21% in cardiac arrest, and 12.14% in HIE, with an overall EEG use of 5.79%.

Table 2 Demographic characteristics of ECMO, TBI, HIE, cardiac arrest and cardiac surgery of the weighted sample

	ECMO	TBI	HIE	Cardiac arrest	Cardiac surgery	Population with EEG indication	Total KID population
Total *N*	1504	9201	4068	2774	4580	18,966	6,675,222
Age [mean (SE)]	2.56 (0.24)	12.81 (0.21)	0.00 (0)	10.87 (0.23)	1.28 (0.10)	7.87 (0.21)	4.49 (0.04)
Gender [*N* (%)]							
Male	858 (57.01)	6419 (69.84)	2315 (56.93)	1699 (61.26)	2580 (56.33)	12,134 (64.02)	3,194,495 (47.87)
Female	647 (42.99)	2771 (30.16)	1752 (43.07)	1075 (38.74)	2000 (43.67)	6820 (35.98)	3,478,334 (52.13)
Race [*N* (%)]							
White	608 (40.45)	4578 (49.76)	1662 (40.85)	1181 (42.58)	1978 (43.18)	8648 (45.60)	3,138,004 (47.01)
Black	240 (15.92)	1363 (14.81)	742 (18.24)	580 (20.91)	501 (10.95)	3009 (15.87)	1,001,246 (15.00)
Hispanic	233 (15.51)	1619 (17.59)	617 (15.16)	466 (16.80)	985 (21.51)	3306 (17.43)	1,290,955 (19.34)
Other	174 (11.56)	726 (7.89)	526 (12.92)	254 (9.15)	625 (13.65)	1905 (10.04)	694,805 (10.41)
Missing	249 (16.55)	916 (9.95)	522 (12.83)	293 (10.55)	491 (10.71)	2098 (11.06)	550,212 (8.24)
Income quartile [*N* (%)]							
Lower quartile	453 (30.56)	2956 (33.07)	1200 (29.93)	923 (34.24)	1267 (28.25)	5851 (31.60)	2,024,589 (30.93)
Second quartile	372 (25.15)	2351 (26.30)	1095 (27.30)	661 (24.54)	1218 (27.16)	4879 (26.36)	1,623,967 (24.81)
Third quartile	352 (23.75)	2045 (22.89)	957 (23.85)	622 (23.07)	1039 (23.16)	4325 (23.36)	1,546,507 (23.63)
Upper quartile	304 (20.53)	1585 (17.73)	759 (18.92)	489 (18.15)	961 (21.43)	3458 (18.68)	1,349,925 (20.63)
Length of hospital stay (days) [mean (SE)]	40.21 (1.44)	11.94 (0.26)	19.07 (0.64)	15.38 (0.78)	32.73 (1.25)	17.67 (0.45)	3.82 (0.04)
Death [*N* (%)]	600 (39.92)	1545 (16.80)	631 (15.53)	1522 (54.90)	321 (7.02)	3977 (20.98)	22,943 (0.34)

Quantitative variables are summarized as mean (standard error of the mean—for population estimates). Categorical variables are summarized as absolute numbers (percentage). All included patients were intubated during the same hospitalization. Patients can have more than one diagnosis, thus, the population with EEG indication is lower than the total sum of all five indications

EEG electroencephalogram, *ECMO* extracorporeal membrane oxygenation, *TBI* traumatic brain injury, *HIE* hypoxic-ischemic encephalopathy, *Population with EEG indication* hospital admissions with ECMO and/or TBI and/or HIE and/or cardiac arrest and/or cardiac surgery, *KID* Kids' Inpatient Database, *SE* standard error

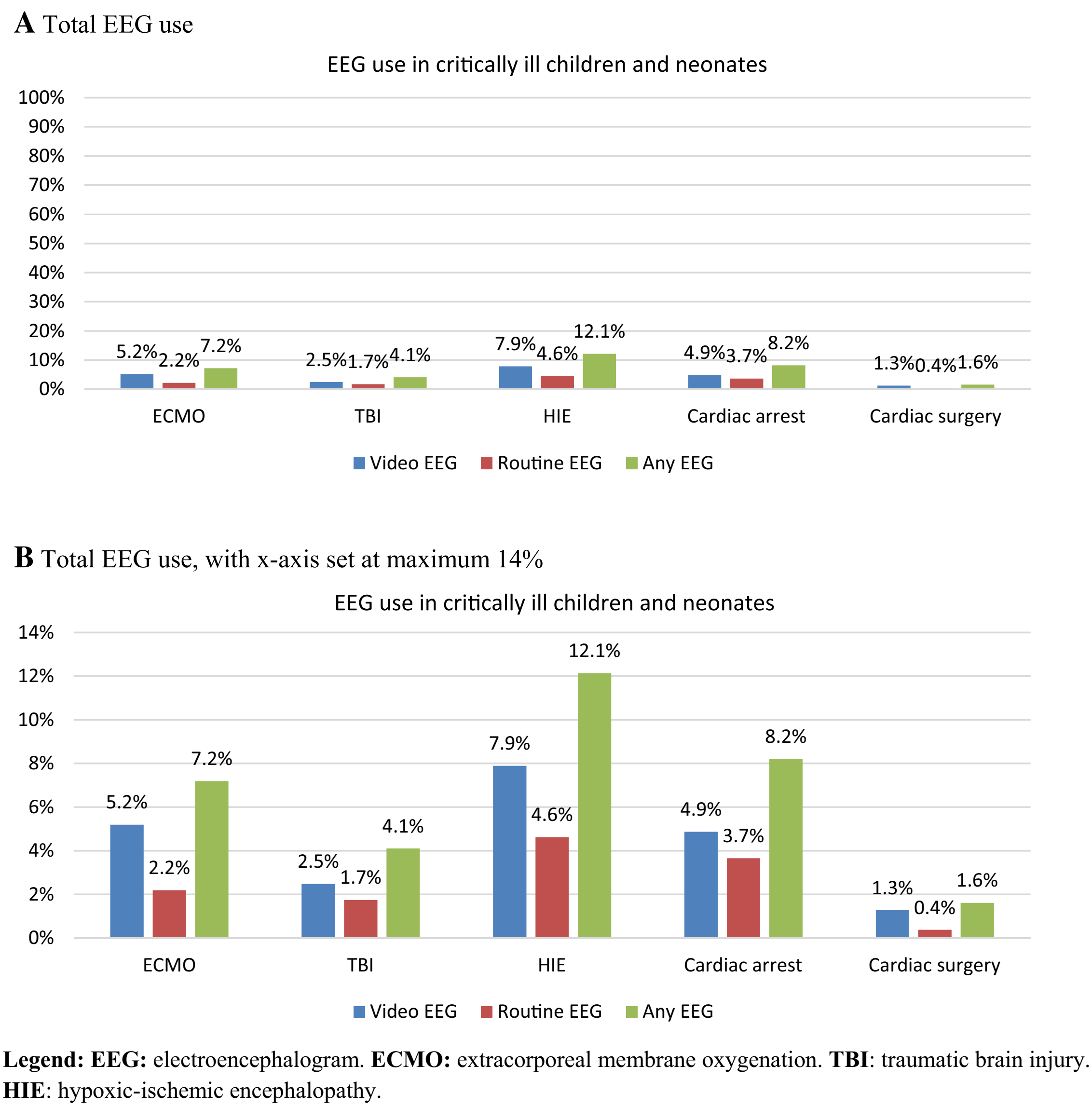

Fig. 1 Use of EEG in critically ill children and neonates in the weighted population. Percentage of EEG use in children with traumatic brain injury, extracorporeal membrane oxygenation, cardiac arrest, and neonates with cardiac surgery and hypoxic-ischemic encephalopathy. *EEG* electroencephalogram, *ECMO* extracorporeal membrane oxygenation, *TBI* traumatic brain injury, *HIE* hypoxic-ischemic encephalopathy

Recommended use of cEEG

Several studies have reported an incidence ranging from 10 to 42% of electrographic seizures in critically ill children who underwent clinically indicated cEEG [1–14, 33], and these could not be detected without cEEG monitoring. Based on the high percentage of electrographic seizures in critically ill patients, the ACNS published specific recommendations for the use of cEEG monitoring in children, adults [15] and infants [16]. These expert-based guidelines recommend the use of cEEG monitoring in different conditions, such as post-convulsive status epilepticus, recent neurosurgical procedures, but also in TBI, ECMO, cardiac arrest, [15] cardiac surgery and HIE [16]. In this guideline, ACNS experts summarized the likelihood of recording seizures on cEEG in these conditions, and this varies between 14 and 79% [15] depending on the study. Another major indication for cEEG is to assess severity and prognosis in encephalopathy [15], in particular after cardiac arrest [21–26] and TBI [23, 27]. However, it is unclear how often cEEG monitoring is being used in critically ill children.

Table 3 Use of EEG of the weighted sample

	vEEG	EEG	vEEG or EEG	Total
ECMO	78 (5.19%)	33 (2.19%)	108 (7.19%)	1504 (0.02%)
TBI	229 (2.48%)	160 (1.74%)	377 (4.10%)	9201 (0.14%)
HIE	321 (7.89%)	188 (4.62%)	494 (12.14%)	4068 (0.06%)
Cardiac arrest	135 (4.87%)	101 (3.66%)	228 (8.21%)	2774 (0.04%)
Cardiac surgery	58 (1.27%)	17 (0.37%)	74 (1.61%)	4580 (0.07%)
Total	821 (3.71%)	499 (2.26%)	1281 (5.79%)	22,127

Categorical variables are summarized as number (percentage)

EEG electroencephalogram, *vEEG* video-electroencephalogram, *ECMO* extracorporeal membrane oxygenation, *TBI* traumatic brain injury, *HIE* hypoxic-ischemic encephalopathy

Table 4 Use of EEG in pediatric hospitals in the USA

	EEG	vEEG	EEG or vEEG	KID database
Total *N*	11,138	30,045	40,596	6,675,222
Age [mean (SE)]	6.50 (0.21)	7.66 (0.13)	7.38 (0.13)	4.49 (0.04)
Female [*N* (%)]	5192 (46.61)	14,208 (47.29)	19,136 (47.14)	3,478,334 (52.13)
Race [*N* (%)]				
White	4416 (39.65)	14,621 (48.66)	18,824 (46.37)	3,138,004 (47.01)
Black	1939 (17.41)	4258 (14.17)	6108 (15.04)	1,001,246 (15.00)
Hispanic	2156 (19.36)	4255 (14.16)	6286 (15.48)	1,290,955 (19.34)
Other	1058 (9.5)	3869 (12.88)	1883 (12.03)	694,805 (10.41)
Missing	1568 (14.08)	3043 (10.13)	4495 (11.07)	550,212 (8.24)
Income quartile [*N* (%)]				
Lower quartile	3180 (29.43)	7027 (23.85)	10,057 (25.33)	2,024,589 (30.93)
Second quartile	2468 (22.84)	6437 (21.85)	8787 (22.13)	1,623,967 (24.81)
Third quartile	2518 (23.30)	6959 (23.62)	9308 (23.44)	1,546,507 (23.63)
Upper quartile	2640 (24.43)	9044 (30.69)	11,549 (29.09)	1,349,925 (20.63)
Hospital duration (days) [mean (SE)]	8.59 (0.50)	5.51 (0.33)	6.19 (0.34)	3.82 (0.04)

Quantitative variables are summarized as mean (standard error of the mean—for population estimates). Categorical variables are summarized as number (percentage)

EEG electroencephalogram, *vEEG* video-electroencephalogram, *KID* Kids' Inpatient Database, *SE* standard error

Use of cEEG monitoring in ICU

An international survey of 330 neurologists reported that 83% use cEEG monitoring at least once per month and that 86% manage non-convulsive seizures at least 5 times per year. However, there was variability in the cEEG indications, timing, duration and treatment [28, 29]. A different survey of 137 intensivist and neurophysiologists in the USA showed that 95% reported using cEEG after the treatment of clinical seizures, 78% in cardiac arrest and 77% in TBI. [30] A study using the adult Nationwide Inpatient Sample (NIS) database from 2005 to 2009 showed an increase of 263% of cEEG monitoring use in mechanically ventilated patients [19]. The routine EEG use also grew but at a rate of 8% per year. A total of 40,945 (8.03%) admissions had a reported EEG or cEEG out of 5.1 million admissions reporting mechanical ventilation [19]. We did not evaluate the use of EEG in the overall intubated population, but focused on specific diagnosis or procedures that have indications for EEG. Our study also differs from these results as it pertains to a pediatric population. We found that the overall use of EEG in these five different conditions was 5.79%, which is concordant with registry-based results on EEG use in mechanically ventilated adults, but much lower than the ones reported in surveys. One explanation could be that in the intensivist and neurophysiologist survey 94% of the hospitals were tertiary care centers [30], while our data include a broader population representative sample with hospitals of different complexities, as well as rural and urban areas. There may also be response bias. Additionally, if a physician reports that cEEG is used, this does not necessarily mean that cEEG is used in all patients, and therefore the survey approaches the question for the physician's perspective, while the KIDS database analysis sheds additional light on this question from an individual patient basis. The distribution of type of EEG suggests that vEEG code is more frequently used among Whites and higher socioeconomic quartiles, although available data do not permit additional conclusions.

Electrographic seizures and outcome

One of the objectives of using cEEG monitoring in critically ill patients is to detect electrographic seizures and status epilepticus, with the assumption that detecting and treating electrographic seizures improves outcomes. A series of 200 children who underwent cEEG showed that patients with electrographic status epilepticus had higher chances of dying (OR 5.1) and worse neurological outcome (OR 17.3); however, patients with electrographic seizures did not have a higher risk of death or negative neurological outcome [13]. Similar results were found in a study with 550 children who had cEEG monitoring in the ICU. Patients with electrographic status epilepticus had increased chances of dying (OR 2.42), but not if they had electrographic seizures (OR 1.78) [14]. However, a series of 204 children showed that electrographic seizures were associated with poor outcome, and that a normal EEG background predicted survival [8]. A different study also showed that cEEG was associated with lower mortality in patients who were mechanically ventilated (OR 0.63). Based on these data, it is still unclear if electrographic seizures are independently associated with outcome, but the evidence suggests that electrographic status epilepticus and the use of cEEG are.

Economic burden

One important factor to consider when increasing the use of cEEG in the ICU is the economic burden. EEG monitoring is a relatively inexpensive test but it is personnel intensive, especially for continuous monitoring. A study including 5949 cEEGs showed that hospitalizations with cEEGs had no significant difference in the cost or length of stay compared to hospitalizations that included a routine EEG [19]. Also, a study evaluated the cost-effectiveness of four different EEG strategies: no monitoring, 1 h of monitoring, 24 and 48 h and found that the incremental cost-effectiveness ratios increase markedly after 24 h of monitoring ($465.67 for patient with detected electrographic seizure within 1 h of monitoring, $1665.63 for 24 h, and $22,648.36 for 48 h) [34]. Based on these findings, these authors recommended monitoring critically ill children with a clinical indication for EEG for 24 h as the optimal timeline to detect seizures [34]. Some studies suggest that some specific patients may even require longer monitoring periods [33, 35, 36]. However, as noted in our data, only a small percentage of patients is being monitored. The first step in evaluating whether the use of EEG is appropriate among critically ill children is to quantify the proportion of children who have an indication for cEEG and who actually undergo cEEG monitoring. Therefore, our data address a gap in knowledge and shows that the proportion of children with an indication for a cEEG who actually undergo cEEG is lower than recommended by most guidelines. Acknowledging that cEEG is underused in critically ill children is the first step towards policies, guidelines and implementation procedures to remediate this underutilization. Improving use of cEEG may be challenging in smaller hospital settings with more limited human and technical resources. National and hospital-based protocols reinforcing appropriate indications for cEEG may eventually increase the number of patients who receive standard of care cEEG monitoring.

Strengths and limitations

The limitations of this study are largely related to the nature of the database. The HCUP database is the largest available database on patient admissions in the United States. It is based on ICD-9 codes from hospital discharge reports. We used these codes to identify diagnoses and procedures, but these codes may not have been used consistently and interchangeably among hospitals. However, some studies have demonstrated a high validity between administrative and clinical data [37–39]. Our main variable was the use of EEG or vEEG; however, we do not know if the EEG was attended, read and interpreted in real time. We also chose five different diseases or procedures that represent critically ill children. In order to avoid the inclusion of follow-up hospitalizations or admissions, in which these conditions would be reported as the medical history, we used mechanical ventilation, as this would reflect that patients were in intensive care. The KID database is based on discharge records, and it does not differentiate between several admissions of the same patient [32]. Thus, the data are not completely independent. However, some of these clinical scenarios (especially the procedures) rarely occur more than once and they happen within the hospital. This sample includes most US hospitals and may reflect one of the most detailed available representations of the prevalence of these conditions.

The main limitation of studies about cEEG monitoring is that they usually include patients who underwent cEEG monitoring—introducing indication bias. By using a large nationally representative database, we were able to report a more accurate estimate on the use of cEEG in critically ill children, and our data, therefore, contribute additional information to the epidemiology of these five different conditions in the USA. We evaluated the use of EEG between 2010 and 2012; recent recommendations from ACNS on the use of EEG in critically ill children will probably increase the use of EEG in the following years.

This study fills a gap in the literature by providing a national estimate of the use of EEG in critically ill children. These estimates may be useful to better understand the use of EEG in the USA in a wide range of hospitals and settings, and not only in highly specialized tertiary centers. The data on EEG underutilization may fuel further studies to understand specific areas where underutilization occurs more frequently, and may also inform and guide public health policies and guidelines to prevent underutilization. This specific dataset was collected prior to availability of the ACNS guidelines and therefore may represent a baseline of cEEG utilization prior to publication of the ACNS guidelines. Future studies may be able to follow up on utilization change, and tentative interventions to improve implementation as applicable.

Conclusion

Among five of the most common indications for EEG monitoring in critically ill children and neonates, the estimated use of EEG is low.

Compliance with ethical standards

Conflicts of interest Marina Gaínza-Lein is supported by the Epilepsy Research Fund. Iván Sánchez Fernández is funded by Fundación Alfonso Martín Escudero and the HHV6 Foundation. Tobias Loddenkemper serves on the Laboratory Accreditation Board for Long Term (Epilepsy and Intensive Care Unit) Monitoring, on the Council (and as Vice President) of the American Clinical Neurophysiology Society, on the American Board of Clinical Neurophysiology, as an Associate Editor for Seizure, as Contributing Editor for Epilepsy Currents, and as an Associate Editor for Wyllie's Treatment of Epilepsy 6th edition. He is part of pending patent applications to detect and predict seizures and to diagnose epilepsy. He receives research support from the Epilepsy Research Fund, the American Epilepsy Society, the Epilepsy Foundation of America, the Epilepsy Therapy Project, PCORI, the Pediatric Epilepsy Research Foundation, CURE, HHV-6 Foundation, and received Research Grants from Lundbeck, Eisai, Upsher-Smith, Acorda, and Pfizer. He serves as a consultant for Zogenix, Upsher Smith, Lundbeck, and Sunovion. He performs video electroencephalogram long-term and ICU monitoring, electroencephalograms, and other electrophysiological studies at Boston Children's Hospital and affiliated hospitals and bills for these procedures and he evaluates pediatric neurology patients and bills for clinical care. He has received speaker honorariums from national societies including the AAN, AES and ACNS, and for grand rounds at various academic centers. His wife, Dr. Karen Stannard, is a pediatric neurologist and she performs video electroencephalogram long-term and ICU monitoring, electroencephalograms, and other electrophysiological studies and bills for these procedures and she evaluates pediatric neurology patients and bills for clinical care.

Ethical standards The manuscript is based on a publicly available de-identified database.

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